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Storm-time relativistic electron modeling using the Salammbô code including trapping boundary measurements from Los Alamos particle detectors on board the Global Positioning (GPS) satellites

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A. Abstract

The Salammbô radiation belt code is a comprehensive diffusive code that models all physical processes governing energetic particle dynamics in the inner magnetosphere in terms of diffusion. The code uses Los Alamos geosynchronous measurements as input, and uses Kp to modulate several of its internal processes: (1) diffusion due to electric and magnetic field variations, (2) plasmapause location (and this location of hiss). The code incorporates a small-scale recirculation mechanism based on combined radial and pitch angle diffusion which has been successfully used to model relativistic particle dynamics. While the code has been successful to reproduce the general dynamic features during storms, as compared to GPS measurements, it does not incorporate the catastrophic losses incurred by encounters with the relativistic electron trapping boundary. Since no reliable model for this boundary exists they are not modeled by the code. We use here in-situ measurements from up to 4 simultaneous GPS satellites, which can measure the boundary directly. We use this data as further input to the Salammbô code, further enhancing it's now-casting accuracy.

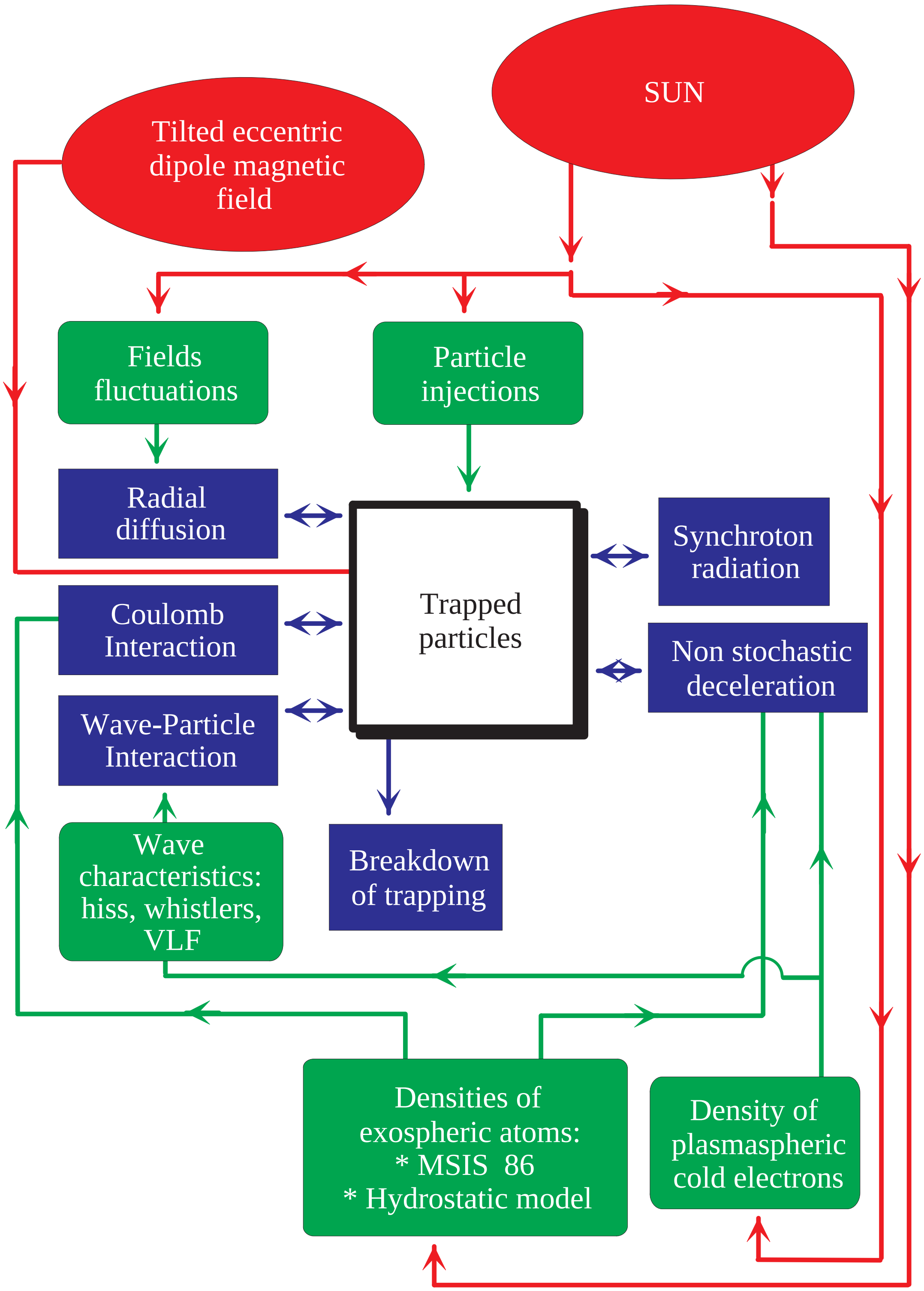
B. Overview

Most storm onsets observed at geosynchronous orbit are accompanied with a dropout in the relativistic electron fluxes, which has traditionally been explained by magnetopause shadowing in combination with the Dst effect [*Roederer*, 1970; *Kim and Chan*, 1997], and recently by strong pitch angle scattering [*Summers and Ma*, 1998; *Lorentzen et al.*, 2001].

Recent observations by the GPS energetic particle detectors show that these losses are observable down to $L = 4$, and can be associated even with very "small" storms ($Dst < 30$).

These losses so far defy parameterization which is needed for any realistic relativistic electron modeling during disturbed times. We attempt here to use in-situ measurements from GPS as a further boundary input to the Salammbô diffusion code.

C1. Salammbô block diagram



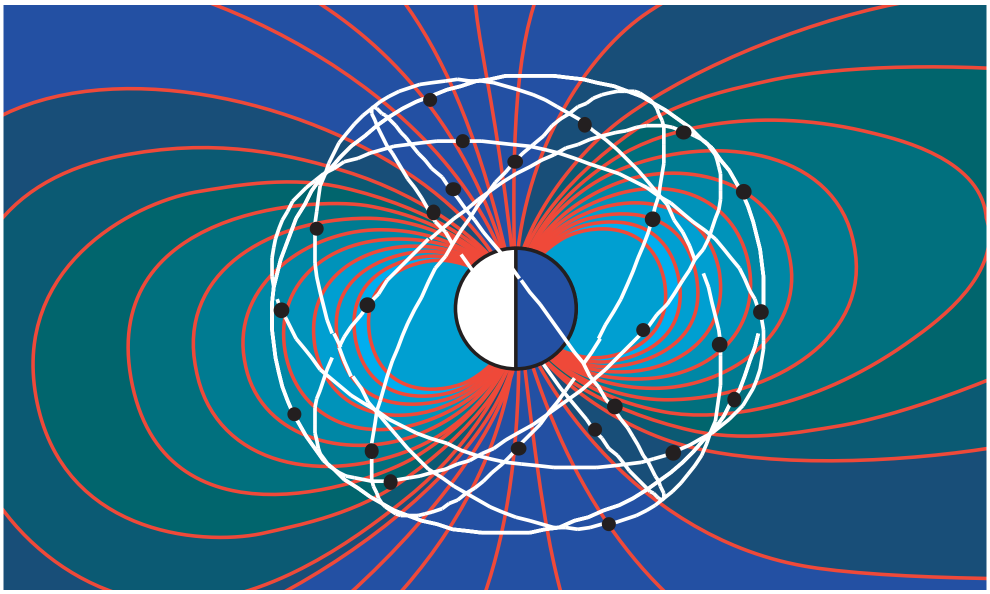
C2. Salammbô operation

- Models all physical processes in terms of diffusion.
- parameterization in terms of Kp:
  - Radial diffusion coefficients
  - Plasmapause position

  Boundary condition is taken from geosynchronous measurements.
- Radial transport is driven by electric and magnetic field fluctuations.
- Wave particle interactions occur mainly near the plasmapause.
- Acceleration of electrons is modeled by a tight recirculation in the vicinity of the plasmapause - thus the location is controlled by Kp.
- NEW: Losses from GPS measurements.

D1. GPS Satellites Energetic particle sensors

100/200 keV	–	10 MeV electrons
5/9 MeV	–	60 MeV protons

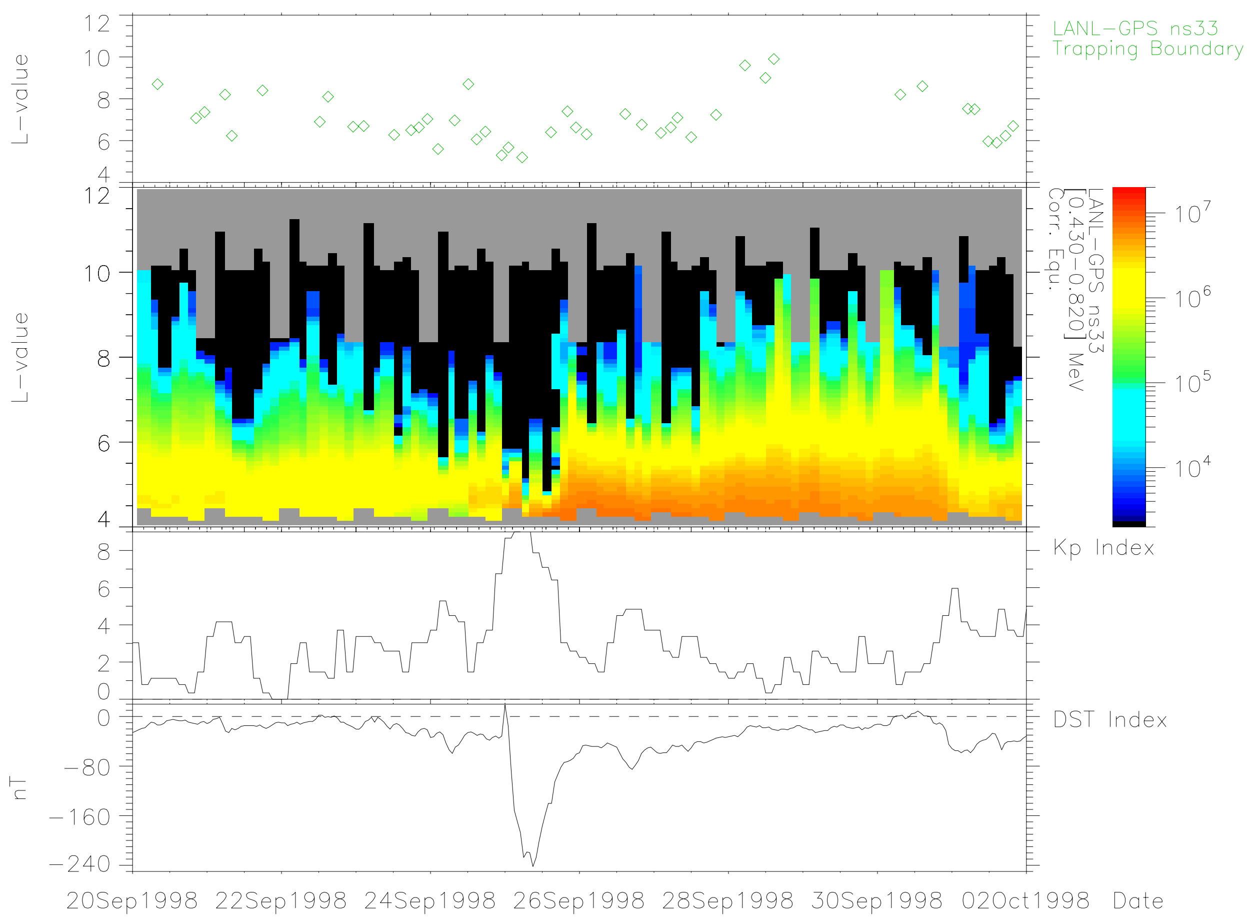


GPS ns08	1983 – 1984	BDD-I
GPS ns10	1984 – 1992	BDD-I
GPS ns18	1990 – 1995	BDD-II
GPS ns24	1991 – present	BDD-II
GPS ns28	1992 – 1996	BDD-II
GPS ns33	1996 – present	BDD-II
GPS ns39	1993 – present	BDD-II
GPS ns41	2001 – present	BDD-IIR
GPS ns54	2001 – present	CXD

D2. **GPS Satellites**
Loss measurements

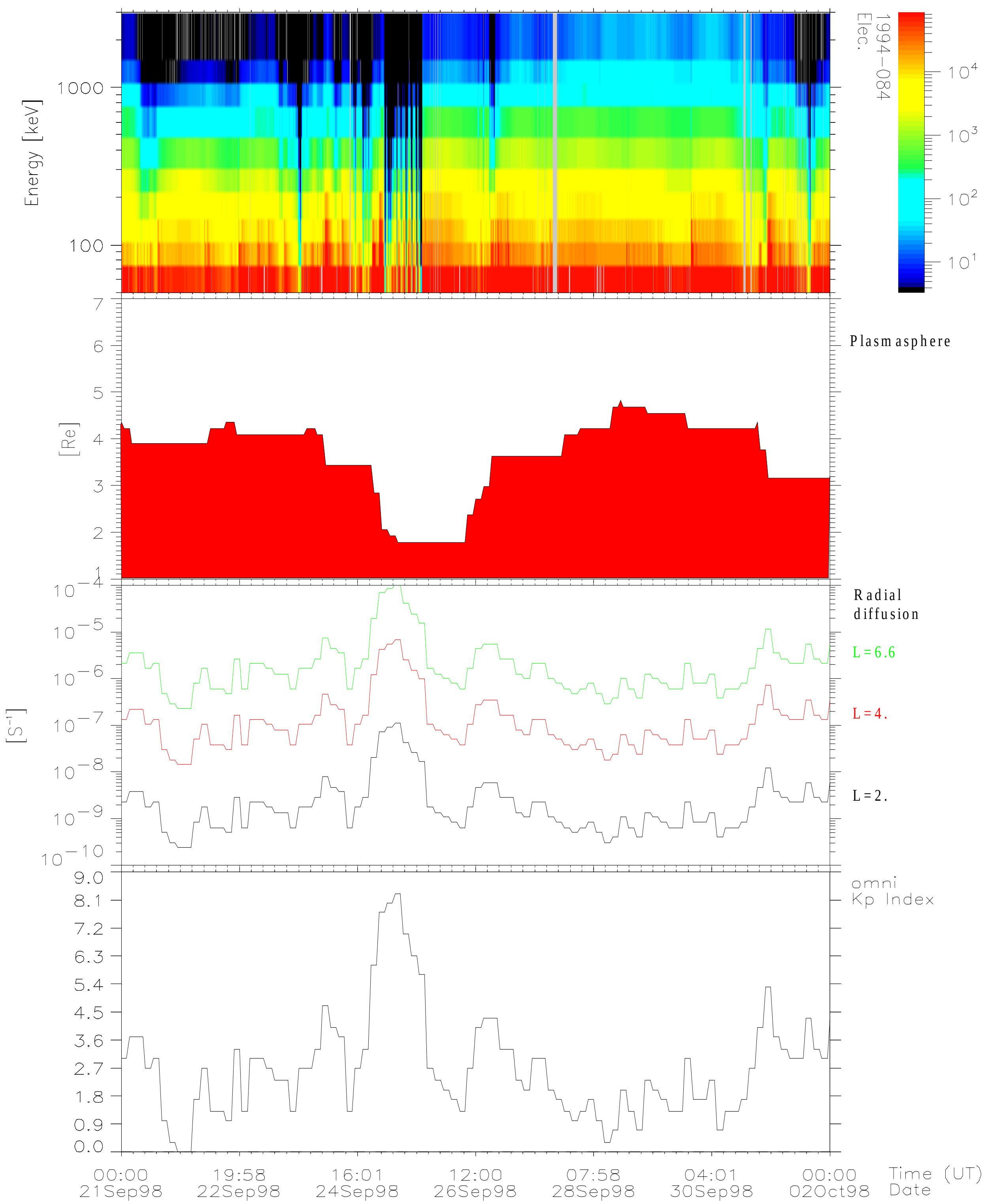
Detect steep radial gradients in GPS passes through radiation belts. Several strict conditions have to be met:

- Count levels must be well above background prior to steep gradient
- Count rates must fall by 0.5 decades in log space
- At least three energy channels need to observe the drop at the same time.



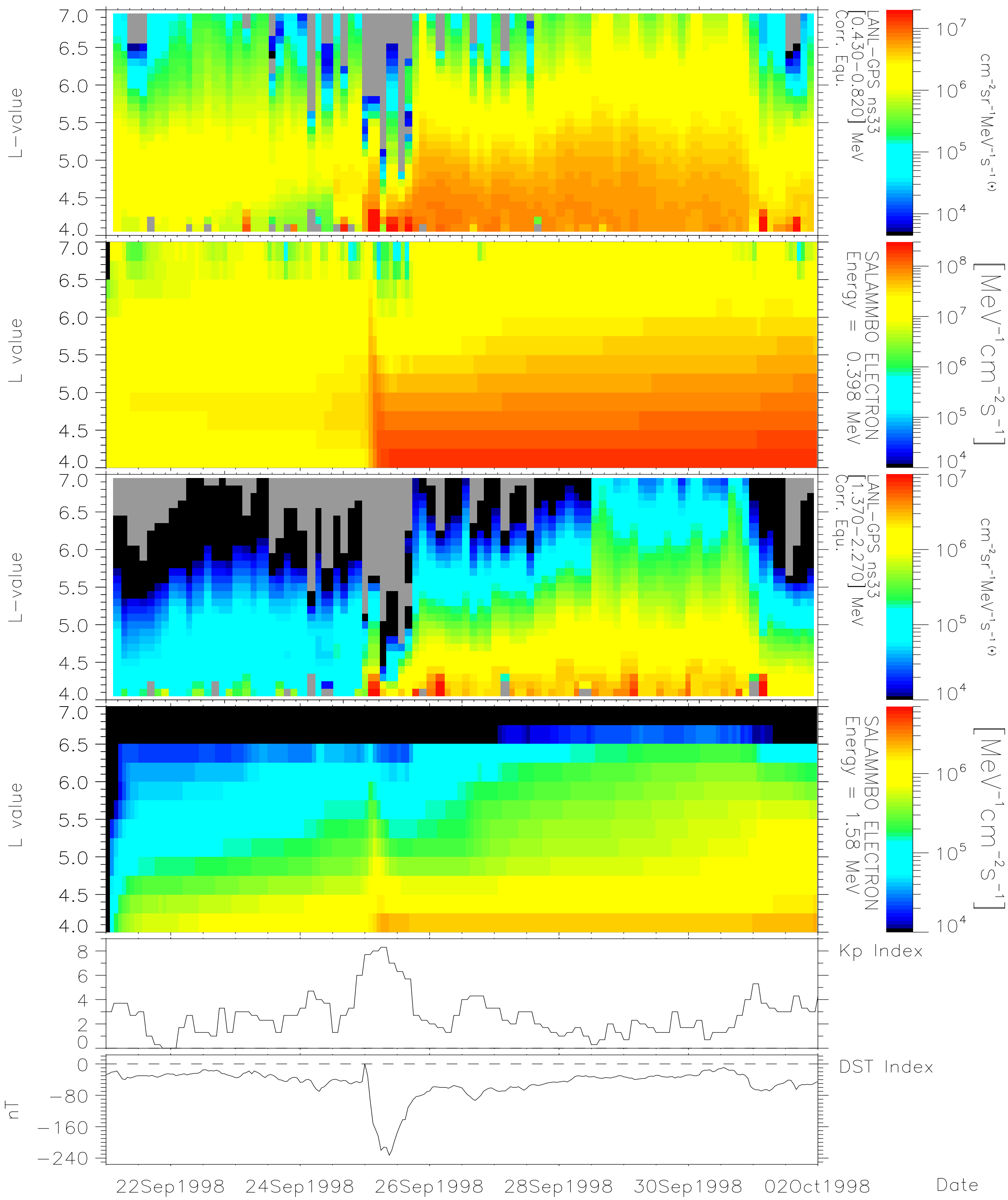
E1.

Results: Sept 1998 Storm Original modeling Inputs

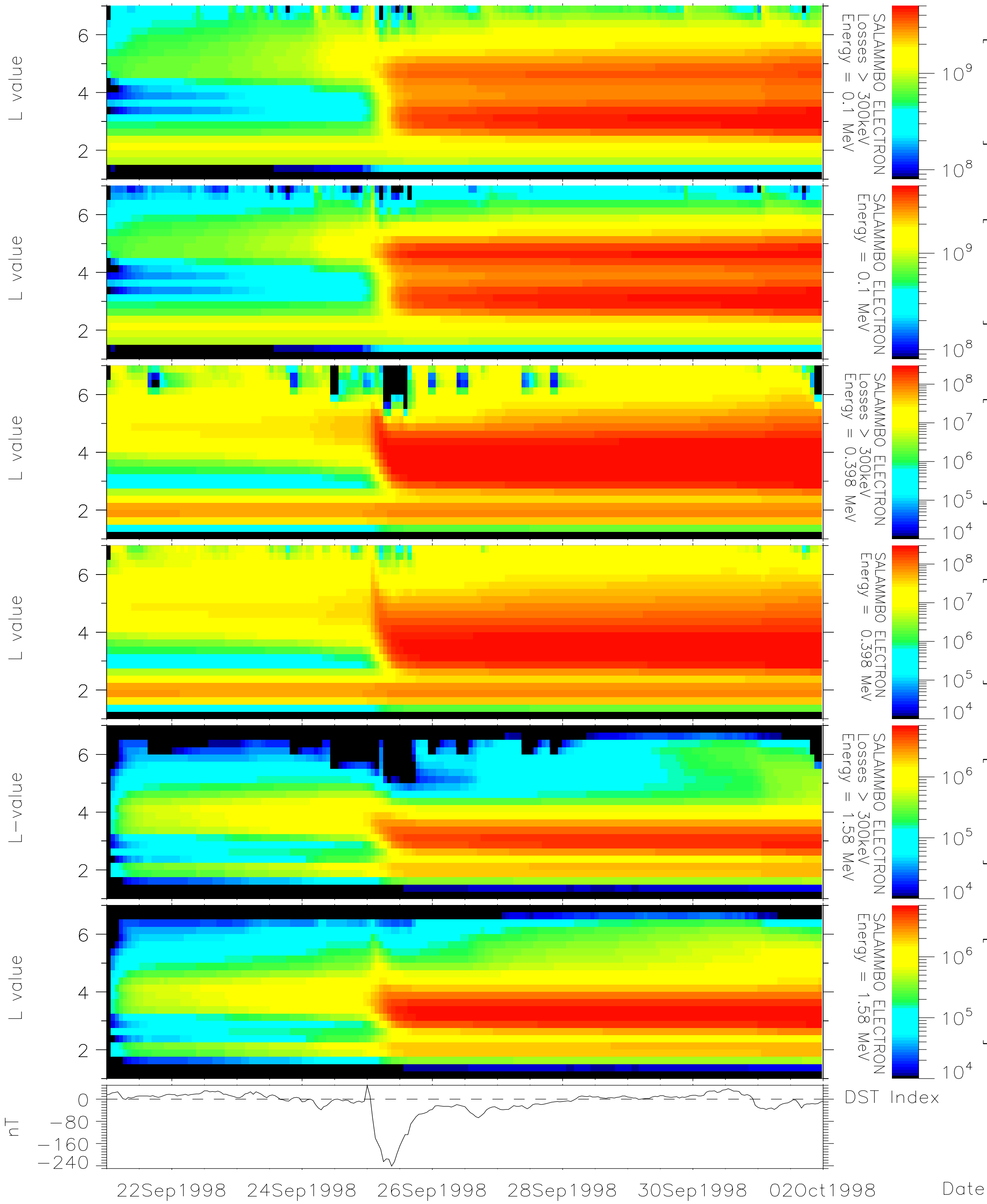


E2.

Results: Sept 1998 Storm
Original GPS comparisons

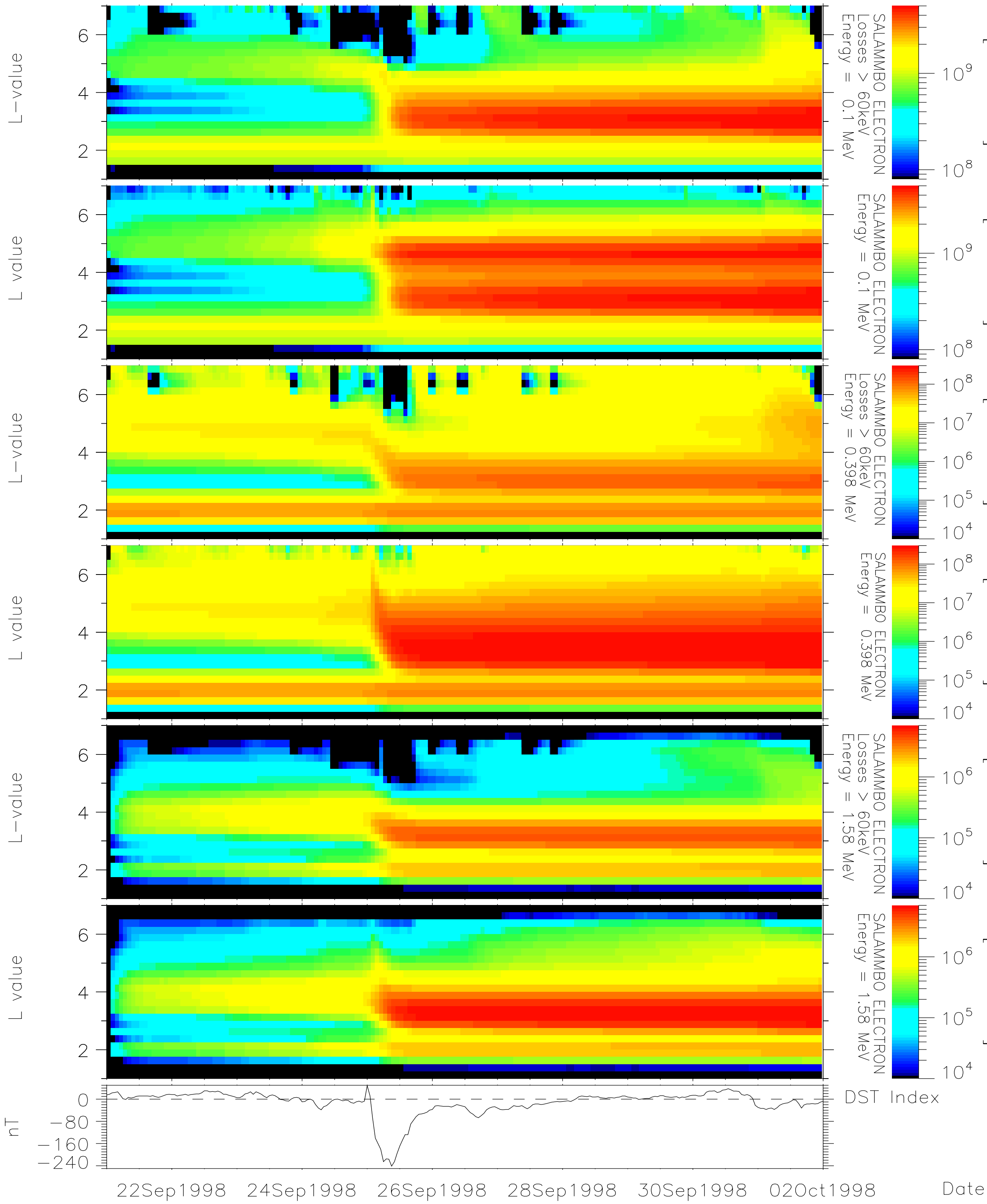


E3. Results: Sept 1998 Storm
Loss modeling - no > 300keV

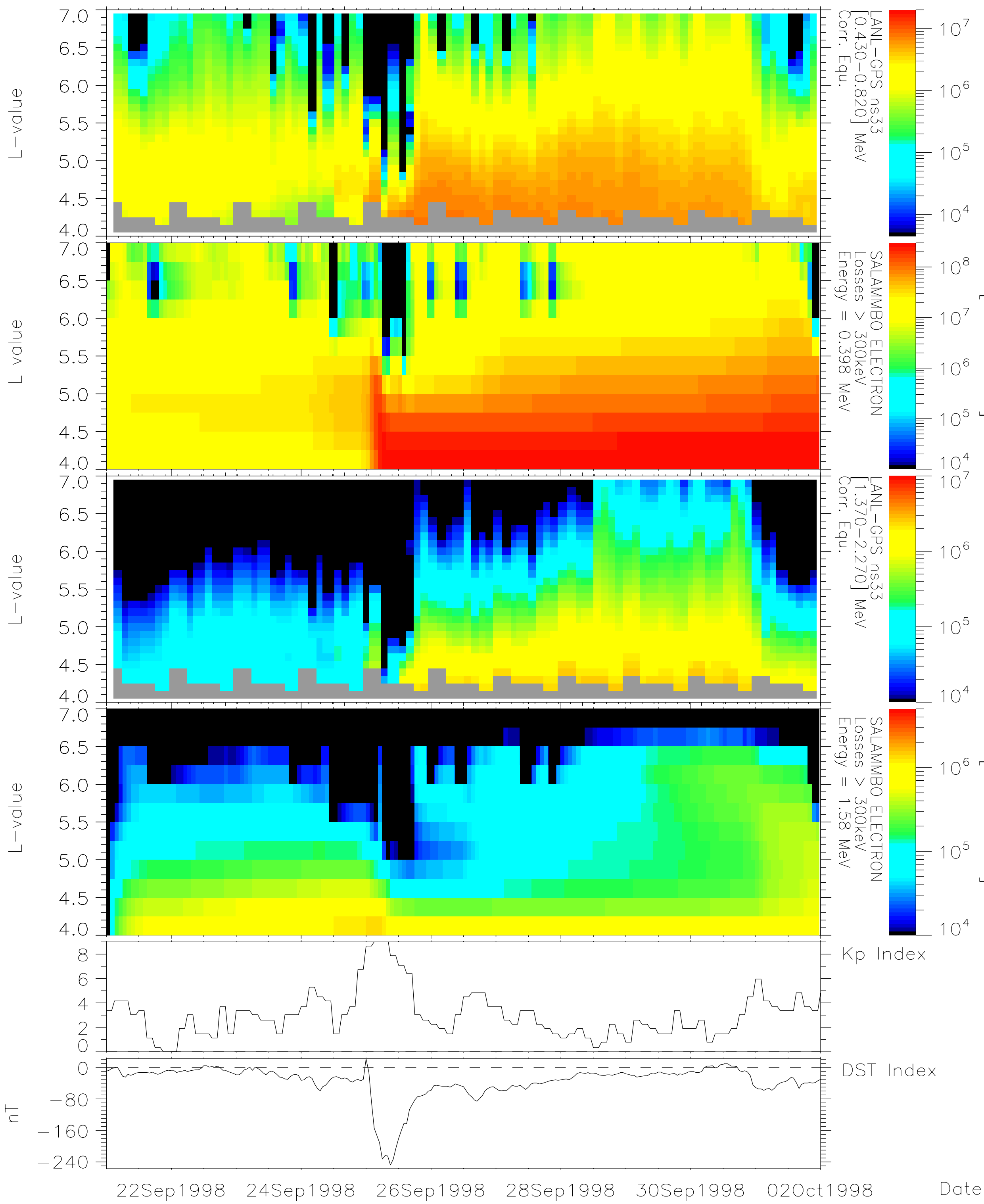


E4.

Results: Sept 1998 Storm
Loss modeling - no > 60keV



E5. Results: Sept 1998 Storm
Loss GPS comparison



F. Summary

- Developed a reliable method to detect relativistic electron "trapping boundary" from GPS measurements.
- Application of new boundary condition to Salammbô yields more realistic comparisons to data, esp. for 1.5 Mev electrons.
- Lower energy limit of "loss" plus duration of loss as a function of energy still unconstrained..
- Use of ALL GPS satellites with energetic particle data will answer timing questions, latest instruments also measure to lower energies ($\sim$100 keV).
- Possible parameterization of losses by indices, solar wind ?

G. References

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Roederer, J. G., *Dynamics of Geomagnetically Trapped Radiation*, Springer-Verlag, New York, 1970.

Summers, D., and C. Ma, A model for generating relativistic electrons in the earth's inner magnetosphere based on gyroresonant wave-particle interactions, *J. Geophys. Res.*, *103*, 20,487, 1998.